EFFECTS OF MOWING AND BURNING ON SHRUBLAND AND GRASSLAND BIRDS ON NANTUCKET ISLAND, MASSACHUSETTS

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ABSTRACT.—Throughout the United States, declines in breeding populations of grassland and shrubland birds have prompted conservation agencies and organizations to manage and restore early-successional habitats. These habitats support a variety of birds, some of which have been classified as generalists; thus, often these birds are thought to be less affected by habitat manipulation. More information, however, is needed on the response of early-successional generalists to habitat management, because conservation agencies are increasing their focus on the regional preservation and management of common species. On Nantucket Island, Massachusetts, the goal of the Partnership for Harrier Habitat Preservation (PHHP) has been to restore more than 373 ha of grassland for the island's population of Northern Harriers (*Circus cyaneus*). This management program has entailed methods such as prescribed burning and mowing (e.g., brushcutting) to restore and maintain grassland habitat. Over a 3-year period, we found that songbird response to burning and mowing varied among species, depending on subtle habitat preferences and the intensity and type of management. In shrublands, Eastern Towhee (*Pipilo erythrophthalmus*) and Common Yellowthroat (*Geothlypis trichas*) abundance declined in mowed areas but were unaffected by prescribed burning. In grasslands, Savannah Sparrow (*Passerculus sandwichensis*) abundance showed no response to either burning or mowing, whereas Song Sparrows (*Melospiza melodia*) preferred unmanaged grasslands. In shrublands, mowing was the most effective method for restoring grassland habitat, whereas prescribed burning had little effect on abundances of shrubland birds and vegetation structure. In grasslands, both mowing and burning were successful in restricting shrubland encroachment and maintaining grassland habitat. *Received 27 June 2005, accepted 1 March 2006.*

Between 1966 and 2004, there have been significant population declines in 10 of 14 (71%) grassland and 16 of 36 (44%) shrubland bird species within the eastern Breeding Bird Survey region (Sauer et al. 2005)—a result of habitat loss and fragmentation (Vickery 1992, Askins 2002, Confer and Pascoe 2003, Dettmers 2003, Vickery et al. 2005). Because of these population declines, prescribed burning and mowing have become increasingly important conservation tools in managing grasslands and shrublands throughout the northeastern United States (Vickery et al. 2005).

Efforts to restore and maintain early-successional areas traditionally focused on providing habitat for rare and threatened grassland specialists. Consequently, researchers often emphasize the effects of habitat disturbance on single species that tend to be habitat specialists (i.e., species with rigid habitat requirements) rather than habitat generalists (i.e., species with broad habitat requirements; Bayne and Hobson 2001, Fort and Otter 2004). As regional programs, such as Partners in Flight (Rich et al. 2004) and the National Gap Analysis Program (Scott et al. 1993), continue to advocate a conservation approach of "keeping common species common," there is a greater need to study the effects of habitat disturbance and management on generalist species. Although studies have addressed the effects of rangeland management on early-successional songbirds in the western United States (e.g., Wiens and Rotenberry 1985, Wiens et al. 1986) and the effects of management on grassland birds in northeastern and midwestern sectors of the country (Bollinger et al. 1990, Herkert et al. 1999, Johnson et al. 2004), no studies have focused on the effects of large-scale grassland restoration on both grassland and shrubland generalists in the northeastern United States.

Massachusetts' coastal sandplain grasslands, heathlands, and shrublands are important regional conservation priorities because they support unique regional biodiversity

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(Barbour et al. 1999). It is estimated that more than 90% of coastal heathlands and grasslands in the northeastern United States have been lost since the middle of the 19th century due to development, cultivation, and shrubland encroachment (Barbour et al. 1999). The largest remaining contiguous areas of sandplain grasslands and coastal heathlands in the Northeast are found on Nantucket Island (hereafter Nantucket; Tiffney and Eveleigh 1985, Dunwiddie 1989). Currently, Nantucket's grasslands and heathlands are being lost to increasing residential development and shrubland encroachment (Tiffney and Eveleigh 1985, Dunwiddie and Caljouw 1990, Barbour et al. 1999), the latter representing an important cause of both habitat loss and degradation for grassland birds.

Many of Nantucket's shrubland and grassland areas have been targeted for restoration and management. In 1996, the Partnership for Harrier Habitat Preservation (PHHP) was formed to develop a large-scale vegetation management program aimed at restoring >373 ha of grassland to create and sustain habitat for Northern Harriers (*Circus cyaneus*), an obligate grassland species that requires relatively open areas for most of its breeding cycle (Christiansen and Reinert 1990, Dechant et al. 2003). This program has entailed two basic methods of restoration and management: prescribed burning and mechanical restoration (i.e., brush cutting and repeated mowing; Combs-Beattie and Steinauer 2001). Although the goals of the PHHP emphasize the creation of habitat for Northern Harriers, Nantucket's shrublands and grasslands support several regionally declining generalist species whose habitat preferences are relatively broad, including Eastern Towhees (*Pipilo erythrophthalmus*; Greenlaw 1996), Savannah Sparrows (*Passerculus sandwichensis*; Wheelwright and Rising 1993), Common Yellowthroats (*Geothlypis trichas*; Guzy and Ritchison 1999), and Song Sparrows (*Melospiza melodia*; Arcese et al. 2002).

Our goal was to document the effects of prescribed burning and mowing on Nantucket's assemblage of shrubland and grassland songbirds. In so doing, our objectives were to (1) document changes in vegetation structure in response to management, (2) identify habitat associations of shrubland and grassland songbirds, and (3) analyze the response of shrubland and grassland generalists to habitat alteration. Habitat restoration can be a powerful conservation tool, but considering the regional goals and objectives of many conservation programs aimed at preserving common species, we believe that it is important to study the effects of habitat management on habitat generalists, as well as specialists.

METHODS

Study areas.—Nantucket (41° 28.3′ N, 70° 1′ W) is about 48 km south of Cape Cod and measures 11 × 24 km (Litchfield 1994). The island contains naturally occurring and regionally rare sandplain grasslands, scrub oak shrublands, and sandplain heathlands (Swain and Kearsley 2001). The sandplain grasslands are dominated by graminoids, primarily little bluestem (*Schizachyrium scoparium*), Pennsylvania sedge (*Carex pensylvanica*), and poverty oatgrass (*Danthonia spicata*). Scrub oak shrublands are dominated by bear oak (*Quercus ilicifolia*) and have an understory of black huckleberry (*Gaylussacia baccata*), bearberry (*Arctostaphylos uva-ursi*), and lowbush blueberry (*Vaccinium angustifolium*; Dunwiddie and Sorrie 1996). Heathlands support many of the same plant species as those found in grasslands and scrub oak shrublands, but are dominated by low-growing black huckleberry, bearberry, and lowbush blueberry (Swain and Kearsley 2001). Despite sharing many of the same characteristic plant species as shrublands, heathlands found along the coastline are noticeably shorter and often intermix and overlap with grassland communities; consequently, we defined grassland/heathland areas as grassland for subsequent analyses (Dunwiddie and Sorrie 1996).

From 1998 to 2001, the PHHP targeted >373 ha of shrubland and grassland for restoration and maintenance (Table 1). Management plans have included prescribed burning on 142 ha of scrub oak shrubland and >26 ha of grassland/heathland, and repeated mowing and brush cutting on 205 ha of shrubland (Table 1). The frequency of management differed among study sites: shrubland areas were burned no more than once, and mowing frequency ranged from 0 (control areas) to 1–3 cuts annually. In addition to these activities, the Nantucket Land Bank Commission began

TABLE 1. Management areas and restoration histories of grassland and shrubland study sites on Nantucket Island, Massachusetts, 1999–2001.

Site name	Area (ha)	No. bird survey plots	Restoration history	Years sampled
Shrublands				
D	19.4	6	Control/burn (2000)	1999–2001
E1	19.3	8	Control	1999–2001
SHRUB	14.2	5	Control	1999–2001
BC	68.0	12	Mow (1998–2001)	1999–2001
A	10.5	4	Mow (1998, 1999)	1999
LB1	19.8	5	Mow (1999–2001)	2000–2001
LB2	19.0	5	Mow (1999–2001)	2000–2001
A2	9.7	3	Mow (2000)	2000–2001
TRI	6.9	3	Mow (2000, 2001)	2000–2001
LB4	21.0	8	Mow (1999–2001)	2001
ABURN	10.9	4	Burn (2000)	2001
E2	16.2	4	Burn (1994)	1999–2001
E3	0.8	1	Burn (1998)	1999–2001
F	4.9	3	Burn (1996)	1999–2001
Grasslands				
LRAM	4.5	3	Control/burn (2001)	1999–2001
HPLAIN	19.0	6	Control	1999–2001
LB3	12.1	5	Control	2000–2001
RAM	30.8	6	Mow (1999, 2000)/burn (2001)	1999–2001
GOLF	6.1	4	Mow (1998–2001)	1999–2001
AIR	7.7	4	Mow (1998–2001)	1999–2001

similar brush-cutting efforts in three separate areas comprising >74 ha. Study sites consisted of areas that were either controls (grasslands, shrublands, or heathlands that had not been managed for at least 10 years) or areas that had received or are receiving management through mowing or prescribed burning since 1988. Given the duration of the management plan, the number of areas being managed and surveyed changed each year (Table 1). Management areas were typically discrete subsets of larger, more contiguous habitats that were receiving a particular treatment. No two adjacent study areas shared the same treatment history, and study areas were spatially separated by other habitat types or barriers (e.g., wetlands, open water, or roads). To avoid disruption due to treatment activities, we collected data only in those areas that were not being actively managed during the summer months of this study. Due to unexpected summer management activities on some study sites, we did not sample every site in each year; thus, the number of observations differed among study sites and sample data were unbalanced (Table 1).

Bird censuses.—In the breeding seasons of 1999–2001, we determined avian abundance of shrubland and grassland songbirds by conducting 10-min avian surveys in fixed-radius, 50-m circular plots along pre-established parallel transects, the length and number of which varied, depending on the size and configuration of each site (Table 1; Bibby et al. 2000). Survey plots were >100 m from any habitat edges and >200 m from other plots (Hutto et al. 1986, Bibby et al. 2000). From 22 May to 10 August during the breeding seasons of 1999–2001, we visited 14 shrubland and 6 grassland sites three times (Vickery et al. 1994). We conducted surveys between 06:00 and 10:00 EDT and began surveys 2 min after arriving at the site, but we did not survey birds during inclement weather, such as rain or high wind (>15 km/hr; Vickery et al. 1994). Because our focus was limited to avian and vegetation changes only within management areas, our protocol purposely did not account for changes along or near habitat edges. For a given breeding season, we considered the maximum number of singing males detected during our three visits as a measure of avian abundance, and combined these data to derive a mean for all survey plots within a particular management area.

Vegetation surveys.—At each survey plot, we sampled the vegetation at 0.5-m intervals along four 50-m transects that radiated from the center of each survey plot in the four cardinal directions (Brower and Zar 1977). This resulted in 400 vegetation sampling points per survey plot. At each sampling point, we recorded the dominant vegetation type and height. We classified vegetation cover into four type categories (sparse vegetation, litter, grass/forb, and shrub) and seven height categories (0, >0–0.1, >0.1–0.5, >0.5–1.0, >1.0–2.0, >2.0–5.0, and >5.0 m. Vegetation data were converted to relative frequencies and, for a given parameter in a given survey plot, we averaged all values from the four transects. This method allowed us to establish a basic portrait of vegetation height and type for each point count and study site.

Statistical analyses.—Our null hypothesis was that that bird densities within control shrublands and grasslands would be the same as those in managed shrublands and grasslands, respectively. We used univariate methods to determine species-specific responses to restoration techniques and vegetation characteristics. We were unable to randomize our treatments because management of this large, multi-agency restoration program was constrained by multiple factors beyond our control. This is not uncommon in "natural experiments" and we employed matching in lieu of a controlled experimental design; that is, we compared managed units with units that were not managed (i.e., control), but were similar to the treated units in terms of proximity and environmental conditions (Johnson 2002).

We used a proportional odds logistic regression model with forward selection to identify significant vegetation predictors of avian occurrence (Hosmer and Lemeshow 1989; PROC LOGISTIC; SAS Institute, Inc. 1990). Heavily skewed data on vegetation and uncommon bird species that did not satisfy normality requirements were converted to detection/non-detection (i.e., presence/absence) data for further analysis. For these data, we used chi-square analysis to determine which vegetation variables influenced the detection/non-detection (i.e., presense/absence) of selected bird species (Kleinbaum et al. 1998); only vegetation variables that were significant ($\alpha < 0.05$) in this analysis were used in the logistic regression models (Hosmer and Lemeshow 1989).

We used repeated-measures analysis of variance (ANOVA) to determine bird species-specific responses to management (Sokal and Rohlf 1995). Due to the unbalanced nature of the study design, we used SAS (PROC MIXED; SAS Institute, Inc. 1990), which allows for interval-independent variables and uses the maximum likelihood method to estimate parameters (Kleinbaum et al. 1998). Study sites that received the prescribed burning treatment were categorized by two post-burn classifications: 1 year post-burn and 2–7 years post-burn. One-way ANOVAs were used to determine differences in vegetation variables within grasslands and shrublands treated with different methods and, because all pairwise comparisons were of interest, we used the Tukey-Kramer method for all multiple-comparison tests (Kleinbaum et al. 1998). We conducted ANOVAs separately on grassland/heathland and shrubland areas for both bird abundance and vegetation data. The densities of three species—Eastern Towhee, Savannah Sparrow, and Song Sparrow—were adequate to meet the requirements for repeated measures ANOVA. We set (*a priori*) a significance level of $P = 0.05$ and a "marginal" significance level of $0.10 > P > 0.05$. We conducted power analyses on ANOVA results at a significance level of $P = 0.05$. Means are presented ± SE.

RESULTS

Changes in vegetation structure.—Mowing and burning had different effects on vegetation structure and composition (Table 2). Mowing in shrublands produced the most notable difference. Mowed shrublands had a greater percent cover of litter (37.7% ± 17.5) than burned (2.3% ± 2.1) or control areas (1.9% ± 1.8; $F_{2,12} = 15.22$, $P < 0.001$). Medium-height shrubs (1.0–2.0 m) were common in control (44.4% ± 12.1) and burned shrublands (47.3% ± 14.5) but significantly less in mowed shrublands (11.1% ± 8.3; $F_{2,12} = 17.82$, $P < 0.001$). We documented similar findings for tall shrubs (2.0–5.0 m; $F_{2,12} = 9.17$, $P = 0.004$). Although not significant at the 0.05 alpha level, medium-height grasses

TABLE 2. Percent cover (SE) for vegetation variables, and results of one-way analysis of variance (ANOVA), testing treatment effects in shrubland and grassland habitats on Nantucket Island, Massachusetts, 1999–2001. Several vegetation variables changed in response to mowing and prescribed burning in shrubland and grassland study sites. In shrubland sites, mowed areas had greater proportions of litter and short shrubs and lower proportions of medium and tall shrubs. In grassland sites, unmanaged grasslands had higher proportions of medium shrubs. Significant values ($P < 0.05$) are in bold.

Variable entered	Control	Burn	Mow	*P*
Shrublands				
Sparse vegetation	0.04 (0.04)	0.08 (0.04)	0.03 (0.04)	0.091
Litter (0–0.1 m)	0.02 (0.02)	0.02 (0.02)	0.38 (0.17)	**<0.001**
Short grass (0–0.1 m)	0.01 (0.02)	0.00 (0.01)	0.07 (0.07)	0.10
Medium-height grass (0.1–0.5 m)	0.16 (0.03)	0.11 (0.11)	0.28 (0.13)	0.079
Short shrub (0–0.1 m)	0.50 (0.19)	0.34 (0.32)	0.24 (0.22)	0.36
Short shrub (0.1–0.5 m)	0.46 (0.06)	0.50 (0.10)	0.72 (0.14)	**0.006**
Medium-height shrub (0.5–1.0 m)	0.39 (0.11)	0.33 (0.10)	0.37 (0.14)	0.82
Medium-height shrub (1.0–2.0 m)	0.44 (0.12)	0.47 (0.15)	0.11 (0.08)	**<0.001**
Tall shrub (2.0–5.0 m)	0.44 (0.09)	0.46 (0.17)	0.15 (0.13)	**0.004**
Tall shrub (>5.0 m)	0.04 (0.04)	0.07 (0.11)	0.06 (0.06)	0.88
Grasslands				
Short grass (0–0.1 m)	0.13 (0.12)	0.30 (0.00)	0.53 (0.17)	**0.046**
Medium-height grass (0.1–0.5 m)	0.66 (0.11)	0.75 (0.01)	0.65 (0.07)	0.43
Short shrub (0–0.1 m)	0.26 (0.02)	0.37 (0.10)	0.32 (0.25)	0.73
Short shrub (0.1–0.5 m)	0.67 (0.10)	0.55 (0.02)	0.39 (0.19)	0.13
Medium-height shrub (0.5–1.0 m)	0.38 (0.07)	0.14 (0.10)	0.13 (0.04)	**0.025**
Medium-height shrub (1.0–2.0 m)	0.08 (0.00)	0.00 (0.00)	0.03 (0.01)	0.67
Tall shrub (2.0–5.0 m)	0.01 (0.03)	0.00 (0.00)	0.04 (0.07)	0.67

(0.1–0.5 m), which were uncommon in control (15.6% ± 3.3) and burned (11.3% ± 11.2) shrublands, were slightly more common in mowed areas (27.7% ± 13.1; $F_{2,12} = 3.14$, $P = 0.080$).

In grasslands, burning and mowing produced notable differences in vegetation (Table 2). Compared with grasslands that had been burned or mowed, control grasslands were characterized by a relatively greater percent cover of short-shrub vegetation. Medium-height shrubs (0.5–1.0 m) were more abundant in control grasslands (37.6% ± 6.7), and less abundant in burned (13.7% ± 10.1) or mowed grasslands (12.7% ± 4.4; $F_{2,4} = 8.37$, $P = 0.025$). Mowed grasslands had higher proportions of short grass (0.0–0.1 m; 52.6% ± 17.0) compared with burned (30.0 ± 0.0%) and control grasslands (13.0% ± 12.0; $F_{2,4} = 6.08$, $P = 0.046$).

Avian response to vegetation.—Shrubland and grassland bird communities on Nantucket were relatively depauperate, a common characteristic of faunal communities on islands (Brown and Lomolino 1998). Important vegetation predictors of Eastern Towhee, Common Yellowthroat, Song Sparrow, and Savannah Sparrow presence varied by species (Table 3). Towhees were positively associated with litter (0–0.1 m) and medium (1.0–2.0 m) and tall (2.0–5.0 m) shrubs, but they were negatively associated with medium-height grass (0.1–0.5 m; Table 3). Unlike towhees, Common Yellowthroats were negatively associated with litter (0–0.1 m) but positively associated with medium shrubs (1.0–2.0 m). Song Sparrows were positively associated with medium-height grass (0.1–0.5 m) and medium shrubs (0.5–1.0 m), but they were negatively associated with litter (0–0.1 m). Savannah Sparrows were positively associated with medium grass (0.1–0.5 m) but negatively associated with litter (0–0.1 m) and tall shrubs (2.0–5.0 m; Table 3).

Avian response to management within shrublands.—Within shrubland areas, we recorded Eastern Towhees, Common Yellowthroats, Song Sparrows, Gray Catbirds (*Dumetella carolinensis*), Eastern Kingbirds (*Tyrannus tyrannus*), Blue Jays (*Cyanocitta cristata*), American Crows (*Corvus brachyrhynchos*), and Prairie Warblers (*Dendroica*

TABLE 3. Proportional odds logistic regression using percent cover of vegetation predictors to model the probability of bird species presence in shrubland and grassland habitat on Nantucket Island, Massachusetts, 1999–2001. Significant values ($P < 0.05$) are in bold.

Variable entered	Estimate	Standard error	*P*
Eastern Towhee			
Bare ground	−0.57	0.40	0.15
Litter (0–0.1 m)	1.35	0.41	**0.001**
Short grass (0–0.1 m)	0.26	0.49	0.60
Medium-height grass (0.1–0.5 m)	−0.85	0.43	**0.05**
Tall grass (0.5–1.0 m)	−1.55	1.07	0.15
Medium-height shrub (0.5–1.0 m)	−0.10	0.69	0.88
Medium-height shrub (1.0–2.0 m)	1.20	0.50	**<0.001**
Tall shrub (2.0–5.0 m)	1.67	0.39	**<0.001**
Tall shrub (>5.0 m)	0.31	0.78	0.69
Common Yellowthroat			
Litter (0–0.1 m)	−0.88	0.38	**0.02**
Short grass (0–0.1 m)	−0.34	0.61	0.57
Medium-height grass (0.1–0.5 m)	−0.26	0.42	0.54
Medium-height shrub (1.0–2.0 m)	1.18	0.62	**0.05**
Tall shrub (2.0–5.0 m)	0.64	0.48	0.18
Song Sparrow			
Litter (0–0.1 m)	−1.09	0.37	**0.004**
Medium-height grass (0.1–0.5 m)	1.97	0.50	**<0.001**
Medium-height shrub (0.5–1.0 m)	1.63	0.54	**0.003**
Tall shrub (>5.0 m)	−1.03	0.83	0.22
Savannah Sparrow			
Litter (0–0.1 m)	−2.85	0.74	**<0.001**
Short grass (0–0.1 m)	0.14	0.45	0.80
Medium-height grass (0.1–0.5 m)	2.13	0.89	**0.02**
Short shrub (0–0.1 m)	−0.26	0.61	0.68
Medium-height shrub (0.5–1.0 m)	−0.32	0.46	0.49
Medium-height shrub (1.0–2.0 m)	−0.53	0.48	0.26
Tall shrub (2.0–5.0 m)	−2.78	0.75	**<0.001**

discolor). Eastern Towhees showed a clear response to management practices in shrublands (Table 4). In two out of the three breeding seasons, Eastern Towhee abundance was greater in control or burned shrublands compared with shrublands that had been mowed. Overall, towhee abundance was greatest in areas that had been burned (1.42/ha ± 0.49), and there was no difference in densities between controls (1.12/ha ± 0.37) and mowed areas (0.66/ha ± 0.50; Fig. 1); however, our power to detect this difference was low (β = 0.09). The abundance of towhees differed significantly among years (Table 4), decreasing in every season from an average of 1.48 ± 0.86 in 1999 to 0.86 ± 0.75 in 2000 to 0.71 ± 0.64 in 2001.

Towhee abundance decreased as the frequency of mowing increased between sites (Table 4). After a single mowing event, towhee abundance dropped from an average of 1.13/ha ± 0.17 to 0.85/ha ± 0.17. After a second mowing, abundance further declined to 0.53/ha ± 0.18, although this decrease was not significant; again, however, our power to detect significant differences was limited (β = 0.3).

We found no significant differences in towhee abundance in relation to time since the most recent burn (Table 4), but power was low (β = 0.21). Although towhee abundance declined slightly in the first year after a burn, this decline was not significant, and abundance in sites that had been burned 2–7 years earlier was not significantly different than the abundance in control areas.

Among the less common shrubland birds, Common Yellowthroats preferred control and

TABLE 4. Repeated measures analysis of variance (ANOVA) testing treatment effects on Eastern Towhees in shrubland habitats on Nantucket Island, Massachusetts, 1999–2001. Densities of Eastern Towhees were most affected by mowing and the frequency of mowing within shrubland sites; prescribed burning had little effect on Eastern Towhee abundance. Significant values ($P < 0.05$) are in bold.

Variable entered[a]	df	Estimate	Standard error	F or t	P
Treatment comparisons	2, 12			4.25	**0.040**
Control versus burn	12	0.30	0.31	0.94	0.63
Burn versus mow	12	−0.76	0.29	2.84	**0.037**
Control versus mow	12	−0.47	0.28	1.64	0.27
Mowing frequency	2, 4			5.25	**0.035**
Control versus 1 mowing/season	8	0.28	0.24	1.22	0.47
Control versus 2 mowings/season	8	−0.78	0.24	3.22	**0.030**
1 mowing versus 2 mowings/season	8	−0.50	0.24	2.04	0.17
Years post-burn[b]	2, 2			0.78	0.51
Year	2, 1			14.56	**<0.001**

[a] Within-treatment comparisons were tested using the Tukey-Kramer comparison (i.e., mowing frequency and years post-burn).
[b] Within-treatment comparisons were not included for prescribed burning because the overall model was not significant, and the yearly differences were not significant.

burned shrublands and avoided shrublands that had been mowed ($\chi^2 = 14.43$, df = 2, $P < 0.001$; Fig. 1). As with Eastern Towhees, the frequency of mowing within a season had a significant effect on Common Yellowthroat presence ($\chi^2 = 17.47$, df = 2, $P < 0.001$), which was greater than expected in shrublands that had not been mowed, but lower than expected after one mowing; no Common Yellowthroats were recorded in shrublands that were mowed two or more times within a season.

Song Sparrow abundance did not differ among shrublands that had been mowed, burned, or left unmanaged ($\chi^2 = 1.97$, df = 2, $P = 0.37$; $\beta = 0.20$; Fig. 1). In addition, Song Sparrow presence did not change significantly with respect to the frequency of mowing ($\chi^2 = 1.66$, df = 2, $P = 0.44$). Neither Common Yellowthroat ($\chi^2 = 3.41$, df = 2, $P = 0.18$) nor Song Sparrow ($\chi^2 = 0.25$, df = 2, $P = 0.88$) presence differed with respect to years since burning.

Avian response to grassland management.—Within grassland areas, we recorded Savannah Sparrows, Song Sparrows, and American Goldfinches (*Carduelis tristis*). Savannah Sparrow abundance did not differ among grasslands that had been burned, mowed, or left unmanaged ($F_{2,4} = 0.04$, $P = 0.96$; $\beta = 0.06$; Fig. 2). Song Sparrow abundance was greatest in unmanaged grasslands (0.60/ha ± 0.09), but was similar in burned (0.11/ha ± 0.08) or mowed (0.11/ha ± 0.09; $F_{2,4} = 8.35$, $P = 0.025$) grasslands (Fig. 2).

DISCUSSION

Management in shrublands.—Our findings suggest that the effects of grassland restoration on generalist species will vary with management type and the subtle habitat preferences of the affected species. Not surprisingly, mowing produced the most noticeable changes in vegetation by reducing tall shrub cover. Mowed areas were dominated by litter and short shrubs and contained greater grass cover. Shrublands that were left unmanaged or burned once were not noticeably different and were characterized by tall shrubs. Due to logistical difficulties, such as the availability of adequate burn days and trained personnel, single burns are common in prescribed burning programs (Combs-Beattie and Steinauer 2001); thus, the results we observed in shrublands burned once could be expected in other prescribed fire programs.

Although several generalist species inhabited the same habitat type, a different suite of vegetation variables affected the presence of each species. Eastern Towhees were positively associated with litter and medium and tall shrubs (1.0–5.0 m), and they were negatively associated with medium-height grass. Common Yellowthroats preferred habitats characterized by no litter cover and medium-height shrubs (1.0–2.0 m). Song Sparrows preferred

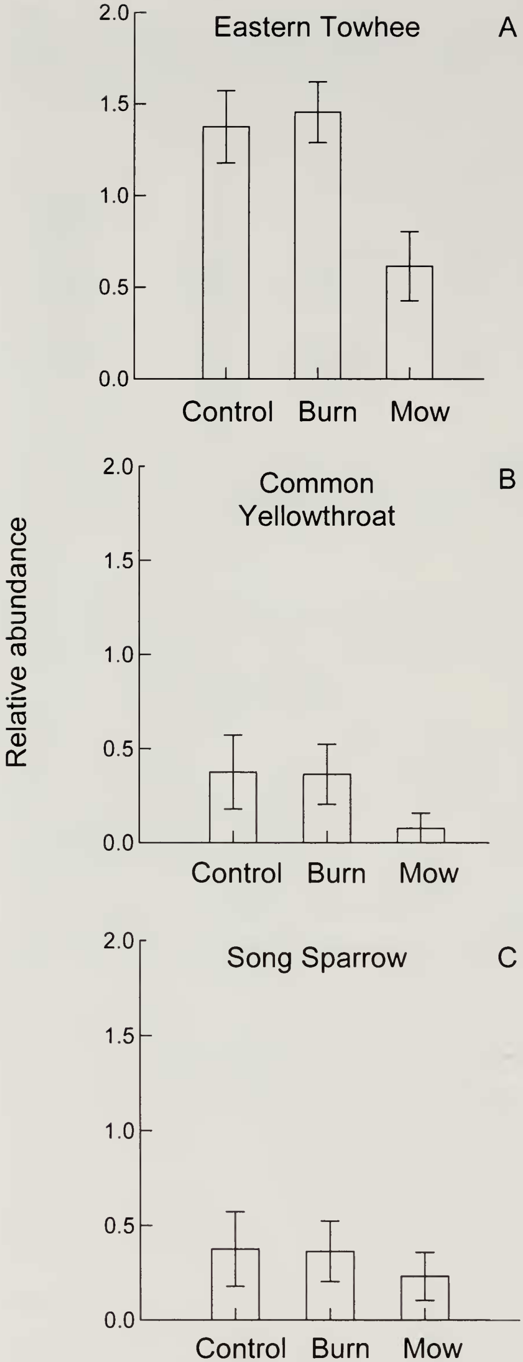

FIG. 1. In shrubland study sites, bird species responded differently to both burning and mowing management. The abundance (± 1 SE) of Eastern Towhees (A) and Common Yellowthroats (B) was most affected by mowing management, but was similar in burned and unmanaged shrublands. Song Sparrows (C) showed little response to management activities. Data collected on Nantucket Island, Massachusetts, 1999–2001.

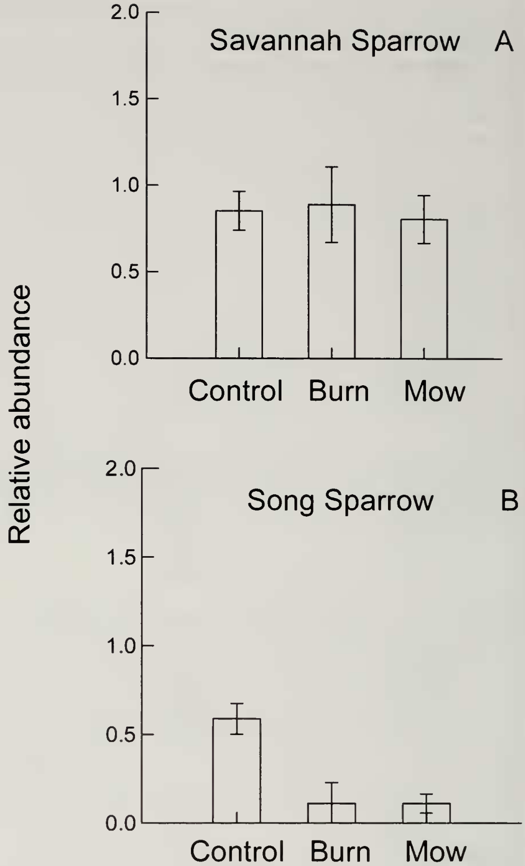

FIG. 2. In grassland study sites, Savannah Sparrow (A) densities (± 1 SE) were unaffected by management type, whereas Song Sparrow (B) densities (± 1 SE) were lower in both mowed or burned grasslands. Data collected on Nantucket Island, Massachusetts, 1999–2001.

areas that had grass and short shrub vegetation.

Despite being generalists, several bird species appeared to respond differently to burning and mowing treatments in shrublands, as has been found in other studies (e.g., Wiens and Rotenberry 1985, Wiens et al. 1986). Eastern Towhee and Common Yellowthroat densities were greater in shrublands that had been burned or left unmanaged, whereas Song Sparrow densities showed no response to either restoration technique (Fig. 1). The effects of mowing frequency were more immediate for Common Yellowthroats; they disappeared after the initial mowing event.

Grassland management.—In grassland habitats, prescribed burning and mowing produced similar results. The purpose of burning and mowing in grasslands was to maintain grassland. Consequently, management in grassland had less impact on vegetation structure than similar restoration techniques used in dense shrublands. Dunwiddie and Caljouw (1990) found that burning and mowing of Nantucket grasslands were equally effective in suppressing shrubs and enhancing grasses. In this study, unmanaged grasslands had greater cover of short shrubs compared with burned and mowed grasslands, and low-growing shrubs often dominated grasslands that were left unmanaged for >6 years (Dunwiddie and Caljouw 1990). Mowing resulted in grasslands with the greatest percentages of short- to medium-height grass cover. These findings suggest that, for a limited number of years, grasslands left unmanaged will continue to provide habitat for some species of grassland-dependent songbirds, but that eventually these grasslands will be succeeded by shrublands (Dunwiddie and Caljouw 1990).

Similar to shrubland generalists, the response of grassland generalists to management practices varied among bird species (Fig. 2). Savannah Sparrow abundance was similar in grasslands that had been mowed, burned, or left unmanaged. Song Sparrows, which were present in both grassland and shrubland habitats, occurred at significantly greater densities in unmanaged grasslands. Both Savannah and Song sparrows were negatively associated with litter and positively associated with medium to tall grass cover. Song Sparrows also were associated positively with short shrubs, whereas Savannah Sparrows were negatively associated with tall shrubs. Song Sparrows required short to medium shrubs, and any grassland management that substantially reduced shrub cover also reduced Song Sparrow abundance significantly.

Some researchers have suggested that site fidelity may preclude birds from responding immediately to management practices (Wiens and Rotenberry 1985, Wiens et al. 1986, but see Vickery et al. 1999). Our findings suggest that species-specific habitat requirements and the magnitude of the management, especially mowing, appeared to outweigh any affects of site tenacity for Common Yellowthroats and Eastern Towhees. The Eastern Towhee's preference for foraging habitat (i.e., litter; Greenlaw 1996) may make towhees less susceptible to burning and mowing than Common Yellowthroats. In the case of Song Sparrows, their lack of dependence on tall shrubs and their preference for grass cover may explain why their densities were not affected by either restoration technique.

The lack of avian response to management may have been a product of the spatial and temporal scales at which this study was conducted. Many avian species respond to habitat alteration at both landscape and patch scales (Herkert et al. 1994, Donovan and Flather 2002, McGarigal and Cushman 2002). The focus of our research, however, was patch-scale disturbances and responses, and not landscape-scale changes. In addition, many grassland birds are area-sensitive and require relatively large grassland habitats (>25 ha; Winter and Faaborg 1999, Mitchell et al. 2000, Johnson and Igl 2001). Because the average size of the grassland habitats included in this study was 13.4 ha (Table 1), many of the grassland areas may not have been large enough to support a diverse community of grassland birds, regardless of management intensity and/or duration. In the future, restoration activities within the shrubland study areas may produce relatively large grassland habitats, but our study was focused on the initial years of management as opposed to the long-term effects of restoration.

Management implications.—Conservation agencies must address several issues regarding the restoration or management of early-successional areas, including the response of generalist species and the type and spatial scale of the management. Despite sharing similar habitat requirements, individual bird species will respond differently to management due to subtle preferences in vegetation structure and composition. In the case of habitat restoration on Nantucket, much of the management had the unforeseen effect of making common species *less* common. Considering these species-specific responses to mowing and burning (even among habitat generalists), managers must proceed cautiously and consider the regional declines of the affected bird species. This is especially true of grassland restoration aimed at shrubland areas, as managers are faced with the dilemma of managing one regionally rare community at the expense of another. In this scenario, a dynamic and diverse set of strategies must be integrated into management such that sites are rotated, allowing some to succeed to later stages before they are disturbed, to provide habitat for both shrubland and grassland songbird communities.

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